# Recent, slow and aseismic movement of an overthrust observed in the Abel sink hole (St Vallier de Thiey, 06, France)

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# Recent, slow and aseismic movement of an overthrust observed in the Abel sink hole. (Saint-Vallier-de-Thiey - Alpes-Maritimes - France).

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**ABSTRACT:**
The main galeries of the Abel sinkhole near Grasse (Alpes Maritimes - France) are developped along a main thrust fault. The study of speleothems proves clearly a recent movement of this fault. The fractures indicate a north-south movement, they are not fossilised by new calcite. A large rock placed under the fault plane rotated during the movement. The sodastraws fixed to the rock are curved. This allows an estimation of the movement speed.

KEY WORDS : overthrust, Provence, sodastraw stalactite, speleothems, tectonics

**RESUME:**

L'inspection d'un petit gouffre donnant accès à un vaste réseau de galeries a permis de constater que ces dernières s'étaient formées sous un plan de chevauchement. L'analyse du concrétionnement montre de façon très nette un mouvement récent du chevauchement qui a cisaillé de nombreux spéléothèmes. Les fractures traduisent un mouvement nord-sud et ne sont pas fossilisées par de la calcite nouvelle. Parmi les indices, un bloc auquel sont fixées des fistuleuses a été mis en rotation. Les fistuleuses se sont courbées sous l'effet du mouvement, enregistrant ainsi la vitesse du déplacement.

MOTS CLES: chevauchement, fistuleuse, Provence, spéléothème, tectonique

## 1. — DESCRIPTION.

### A. — Location (fig. 1)

The Abel sink hole (inventory number 129 O2) or Lèque sink hole, is located in south eastern France, in Alpes Maritimes, 3.5 km south-west of Saint Vallier-de-Thiey and a few hundred meters before La Lèque pass.

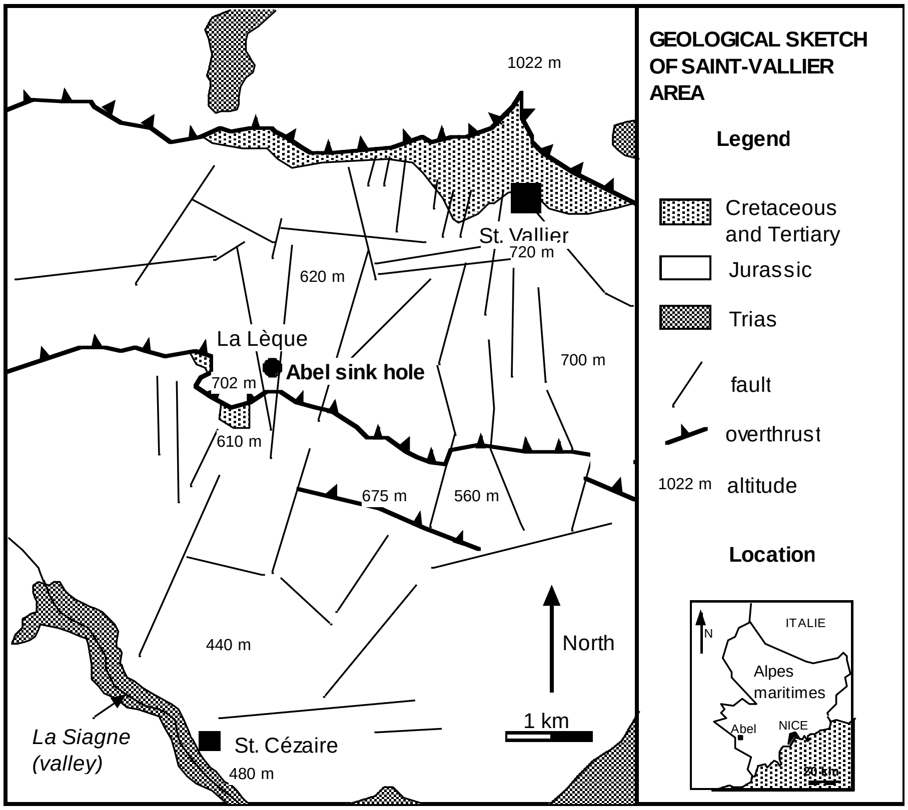



**Figure 1:** geological sketch of Saint-Vallier area where Abel sink hole is located (from Mangan, 1997).
*Schéma géologique du secteur de Saint Vallier où se situe l'Aven Abel (d'après Mangan, 1997)*

### B. — Description (fig. 2)

Several vertical pits lead to a network of galleries, at a depth of 80 m deep. Toward the north, after a small room, a large gallery steadily descends until a vertical passage with several pits at a depth of 150 m. From this point a gallery which is roughly symetrical to the previous one, goes up to a depth of 106 m.

The series of pits conducts to several muddy and narrow passages till a depth of 326 m. This part, which is close to the local karstic water table, is flooded during high water periods.

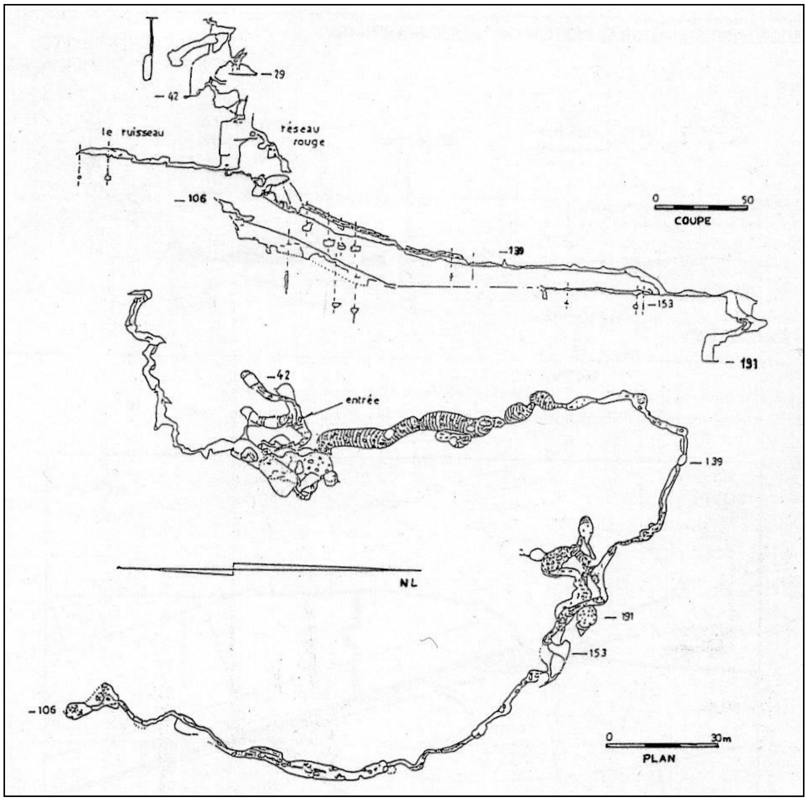



**Figure 2:** Map and cross section of Abel sink hole (galleries from -191 m to -326 m are not figured) (from Hotz, 1997).
*Plan et coupe de l'Aven Abel (les galeries entre - 191 m et -326 ne sont pas figurées) (d'après Hotz, 1997).*

## 2. — GEOLOGY

### A. — Geological environnement (from Mangan, 1997)

The area of Saint Vallier and Saint Cézaire plateaux is part of the sedimentary cover of Tanneron metamorphic block and is more or less folded by the progression, toward the south, of the sedimentary cover of the Alps (Préalples) (fig. 3).

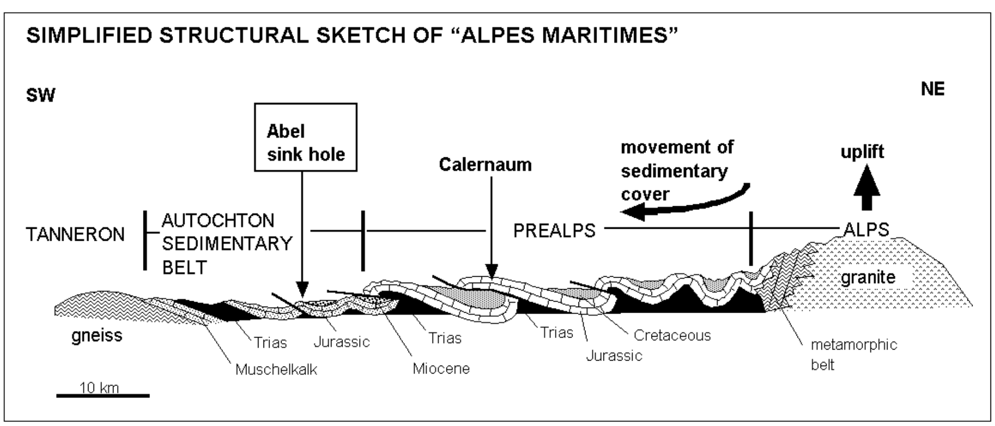



**Figure 3:** Simplified structural sketch of Alpes Maritimes between Mercantour and Tanneron.
*Schéma structural simplifié des Alpes Maritimes entre le Mercantour et le Tanneron.*

The sedimentary rocks are organised in successive halos around Tanneron gneissic block. They include from south to north and from surface:

- 50 m of Werfenien sandstone,
- 200 m of Muschelkalk limestone and dolomite,
- about 400 m of Keuper clays with gypsum and dolomite masses,
- 30 m Rhetien clay limestone,
- 600 to 700 m of Jurassic limestone,
- A variable thickness of Cretaceous marls and marly-limestones as well as remnant parts of Tertiary rocks that are preserved into grabens or synclines.

The tectonic history of this area includes several episodes.
After the Provençal Phase, some light SW-NE open folds were cut by N-S grabens during Oligocene. In the Pliocene, during the Alps uplift, a N-S shortening occured, with creation of E-W thrust faults and numerous NNE-SSW and NNW-SSE strike-slip faults.
At present time, Saint-Vallier and Saint-Cézaire plateaux are organised in a succession of Jurassic limestone anticlines, overthrusting toward south narrow synclines that are filled with Cretaceous and Tertiary impervious rocks (fig. 1).
The main karstic units are Muschelkalk limestone and the whole Jurassic series. The impervious lithological lower levels are respectively Werfenian and Keuper.
Karstification in the study area is established in Jurassic series and is organised according to fracturation and position of impervious levels : Keuper clays and Cretaceous marls that surround Jurassic limestone. These levels may also have abnormal positions caused by thrust faulting.
The underground water of Abel sink hole participates in feeding the Foux-de-Saint-Cézaire spring in the Siagne valley. This is the main karstic spring in that area. The already explored karstic network is several kilometers long. Underground circulation is blocked at the limestone basis, on Rhetian and Keuper impervious levels.
On account of still active alpine tectonics, this area should theoretically present evidence of modern movements. We have observed such evidence in the Abel sinkhole.

**Photographie 1**: General aspect of the thrust fault plane in the main gallery of Abel sink hole. The passage is digged in the impervious crushed formation, the ceiling is formed by the lower part of a limestone bed.
*Aspect général du plan de chevauchement dans la galerie principale de l'aven Abel. Le passage est creusé aux dépens de la formation broyée imperméable. Le plafond est formé d'une surface inférieur de banc.*

**B. — Geological decription of the cave** (fig. 4 and 5)
The sink hole entrance is at the upper part of the Lèque anticline that overthrusts towards the south, the St. Cézaire syncline. At the basis of the thrust fault, remnants of Miocene conglomerates and beige marls, are present.
The cave has been studied to a depth of 140 m, in the main gallery.
The entrance is in the middle part of the Bathonian series. Then the pits cross the lower Bathonien, Bajocien and Hettangien.
In the last pit, important fractures affect the walls. At the depth of 70 m, we cross a chaotic zone with green clay intrusions in several places. Then the thrust fault plane is visible. It forms the ceiling of the main gallery (ph. 1). It is the lower plane of a limestone bed, with N-S striations. Under the plane is a grey crushed formation that is difficult to identify. It contains small angular rocks of dolomite in a beige sandy clay matrix. It is probably crushed Hettangien or Rhetien rocks, but it may also be of Miocene age.

The gallery develops, below the thrust fault limestone ceiling, in this impervious formation. Near the depth of 150 m, the cave crosses the impervious level and penetrates into the limestone of the lower unit.

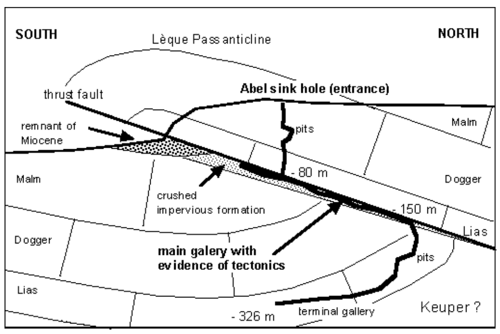
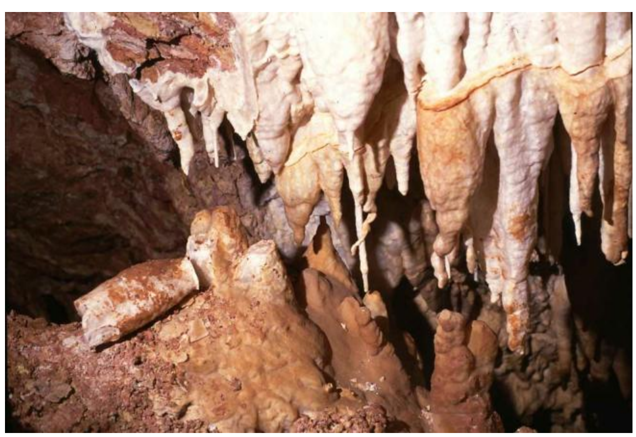



**Figure 4:** Simplified geological cross section of Abel sink hole.
*Coupe géologique simplifiée de l'Aven Abel.*



**Photographie 2:** Abel sink hole. Speleothems broken by the thrust fault movement. At left side a small column is tilted.
*Aven Abel. Massif de concrétions brisées par le mouvement du chevauchement. A gauche une petite colonne a basculé.*

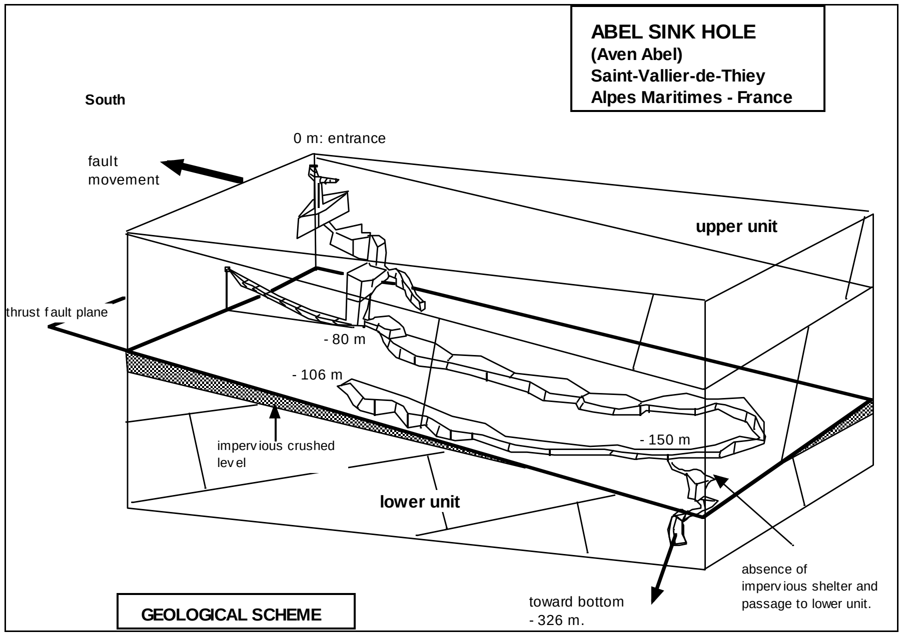



**Figure 5 :** Block diagram of Abel sink hole in its geological environment.
*Bloc diagramme de l'Aven Abel et de son environnement géologique.*

## 3. — STUDY OF TECTONIC MOVEMENT SIGNS

### A. — Classical signs.

The possibility to follow the thrust fault plane for several hundred meters, as was done in the Calernaum sink hole (Gilli, 1992), allows to see if the fault has moved since the digging of the cave.

Many signs were observed, similar to previously described ones (Bini et al., 1992; Gilli, 1986):

- limestone fractured after the karstification.

  Before arriving to the main gallery, several fractures that affect the limestone wall of the last pits are visible. These fractures cut karstic features and are neither enlarged by karstic erosion, nor covered with calcite.

- broken and tilted columns.

  In the main gallery some speleothems are established between the roof (thrust fault plane) and the soil (impervious crushed formation). The movement of the fault has broken or tilted these formations. The shape and the direction of the fractures indicate that it is not possible to invoke a subsidence movement that could have affected the lower formation.

- decapitated stalagmites (ph. 2).

  During the fault movement speleothems that were fixed to the roof struck the top of stalagmites and caused their rupture.

- fractured flowstones.

  Flowstones that cover the lower formation are fractured by the fault movement. In a same way as for previous observations, the shape of the fractures is not compatible with subsidence .

The figure 6 synthesizes these observations.

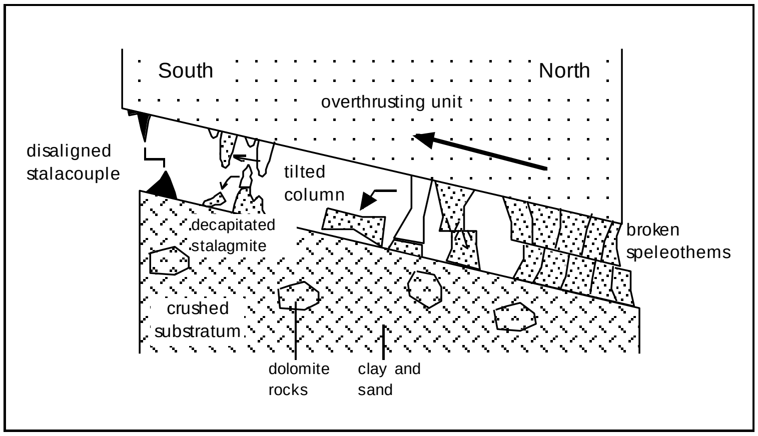



**Figure 6 :** Main signs affecting the speleothems of Abel sink hole.
*Principaux indices affectant les spéléothèmes de l'Aven Abel.*

Near the depth of 140 m, a stalagmitic floor laying on the gallery substratum shows a reverse fault (fig. 7). A similar observation was made in Calernaum without being sure that it was the result of tectonic movement. Calernaum is located in Préalpes, in Calern limestone unit, 12 km north-east of the Abel sink hole.

The previous features look very young because of the absence of calcite covering the fractures. Calcite precipitation is active in this geographical area. Recent and active speleothems are visible in the whole cave. Near the evidence, water drips from the stalactites and recent calcite is visible. The age could be less than 100 years

The observed displacement is some centimeters and the speed should be about 1 mm per year.

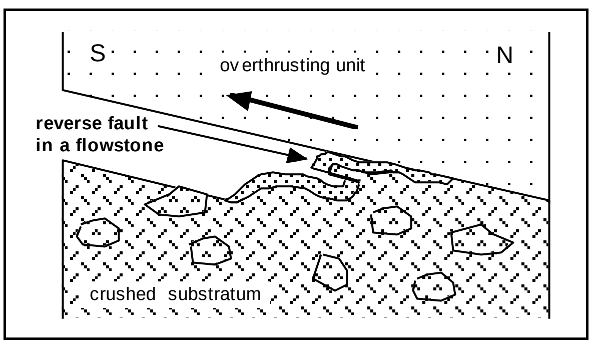



**Figure 7**: Reverse fault affecting a flowstone in Abel sink hole.
*Faille inverse affectant un plancher stalagmitique de l'Aven Abel.*

**B. — Curved soda straws.**

The previous observations are classical, but a very unusual sign has been observed in Abel sink hole. At the base of the first pits series, in a small room, a pluri-metric rock is wedged under the thrust fault plane. Several soda straws have grown below the rock. The movement of the thrust fault has induced a rotation of the rock, tilting its soda straws. As they continued their vertical growth during the fault movement, the soda straws are now curved (fig. 8) (photo. 3). Their form is proof of a slow movement.

Studying the rock geometry and the soda straw ages could permit the precise calculation of the speed of the thrust fault movement.

Similar observations were done in Chemin-de-Castellaras cave (Gilli et al., 1994) which was affected by a landslide.

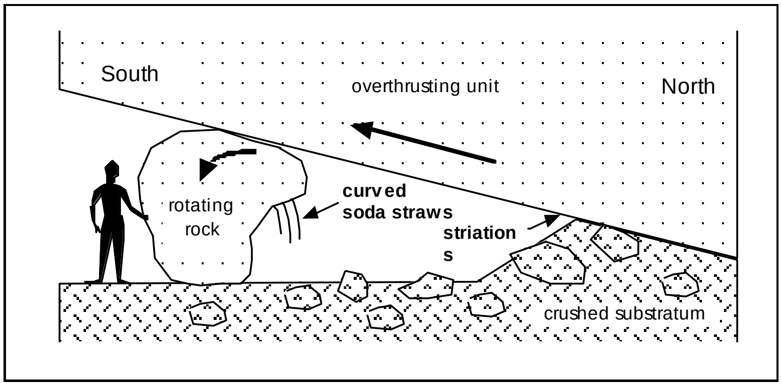
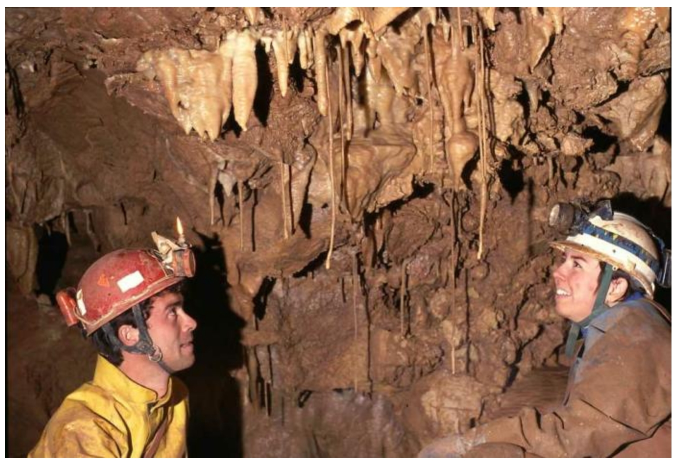



**Figure 8:** Curved sodastraws under a rock that rotates under the thrust fault plane.
*Fistuleuses courbées sous un bloc en rotation sous le plan de chevauchement de l'Aven Abel.*



**Photographie 3**: Abel sink hole. Curved sodastraws below a rock that rotates during the fault mouvement.
*Aven Abel. Fistuleuses courbes fixées sous un bloc en rotation à cause du mouvement de la faille.*

## 3. — CONCLUSION:

The inspection of the speleothems proves the present activity of the Lèque thrust fault with a possible speed of 1mm per year. The movement has stopped in the past, allowing the growth of speleothems, then a new movement has affected the cave formations. Among the speleothems, the soda straws are very interesting movement recorders.

Such geological environment is not rare in Alpes Maritime where several sink holes cross thrust faults: Aven du Calernaum (Calern Plateau), Réseau Claude (Caussols Plateau), Gouffre Samson (La Brigue). Their study could help to describe the kinematics of folds and faults in the Nice Prealps.

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